Applying NABERS IE to a University Building in the UK

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ABSTRACT HEADING

It is no longer sustainable to look at the performance of buildings in isolation of people that use them. This paper examines what is involved in assessing how a building performs for people. The Rose Bowl at Leeds Beckett University is an iconic building designed to BREEAM Excellent. The experience of staff and pupils in classrooms, offices and lecture theatres was proving to be less than excellent. In order to assess and quantify the different parameters that characterize the Indoor Environment (IE) an Australian Government developed tool, NABERS Indoor Environment was used to evaluate the Rose Bowl. The results of the assessment revealed that the IE in the Rose Bowl less than optimal for staff and student health and weelbeing. There were shortcomings in thermal, acoustic and lighting comfort. In addition, indoor air quality (IAQ) was also not optimal for people. The most significant finding was elevated levels of formaldehyde, which can have significant effects on occupant health. As a consequence of the study the facilities management team were able tp react in a way that mitigated any effects upon human health. This was achieved by enhancing ventilation rates in certain room locations, even when they were not in use. This paper shows how balancing energy efficiency strategies is required in order to maintain healthy working places.

INTRODUCTION [LEVEL 1 HEAD]

The Rose Bowl building in Leeds is an iconic working and teaching centre which has been designed as a building that is concerned with sustainability and the wellbeing of people. There are a few rating schemes that examine Indoor Environment Quality (IEQ) for buildings, however, these tend to pay little attention to the issues around health and wellbeing of the occupants as wide issues of sustainability are set as higher priorities (e.g. BREEAM and LEED). Rating schemes that take an independent look at IEQ include the National Australian Built Environment Rating Scheme (NABERS) and the younger scheme, the WELL building standard.

The NABERS was launched in 1998 with an energy rating scheme and has been developed over the last two decades to now include four core tools, namely NABERS Energy, Water, Waste & Indoor Environment (IE). NABERS IE for offices has been used for approximately 10 years and is an established assessment process for measuring how office buildings in use are delivering healthy and comfortable indoor environments for people. It has been used in many buildings in Australia and is increasingly being applied in other parts of the world. A NABERS IE protocol, adapted for teaching and office spaces, was selected by Leeds Beckett University to evaluate the performance of one of its iconic Rose Bowl building.

Sustainability was an important part of the design concept for the 10,000 m² space and the project has gained a BREEAM Excellent score. An element of health and wellbeing is examined within BREEAM, however this is a relatively small consideration within the overall scheme and not based on actual IEQ measurements. NABERS IE offered a comprehensive performance-based assessment to measure how well the building performs for the people that work within it.

There are five specific categories that are assessed for IEQ under the NABERS IE approach: indoor air quality (IAQ), thermal comfort, acoustic comfort, lighting comfort and occupant satisfaction through surveys. There are

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three levels of assessment available, base, tenancy and whole building. The **Base Building assessment** is designed for building owners and managers, who generally control and maintain the thermal services provided, air systems and building cleaning and the ability for the building to minimise external noise. The **Tenancy assessment** is designed to measure the indoor environment parameters directly controlled by the tenants such as the materials used in an office fit-out, lighting and internal noise. The **Whole Building assessment** is for organisations that both own and occupy their office building. Within each category there are specific parameters that are examined with internationally recognised guidelines underlining good performance for a building. Since the Rose Bowl building is both owned and occupied by Leeds Beckett University the 'whole building' rating assessment was used and applied to the teaching and office environments.

METHODOLOGY

In the case of the 'whole building' rating all parameters covered by NABERS IE need to be measured and this approach was taken examining IEQ at the Rose Bowl. Table 1 outlines the different parameters, respective thresholds and methods used. The ***** demotes additional pollutants that were measured out of interest and as required by the WELL Building Standard.

Table 1. IEQ parameters and internationally recognised thresholds, for whole building assessment

IEQ parameter	Cited threshold	Reference	Method/Instrumentation
Air speed	< 0.2 ms-1	NABERS	Graywolf IQ-610 (5 min log)
Temperature	21-24 °C	ASHRAE 55	
Relative humidity (RH)	30-70 %	ASHRAE 55	
Carbon dioxide (CO_2)	1000 ppm 800 ppm	ASHRAE 62 WELL	
Carbon monoxide (CO)	9 ppm	LEED V4/ WELL / NABERS	
Ozone (O_3)*****	80 ppb 51 ppb	LEED V4/ NEPM/ WELL/WHO	
Particulates (PM_{10})	50 μg/m³	LEED V4/ WELL / NABERS	GrayWolf PC-3016A (5 min log)
Fine particulates (PM2.5)*****	15 μg/m³	LEED V4/ WELL	
Total volatile organics (tVOC)	500 μg/m³	LEED V4/ WELL / NABERS	EPA Compendium Method TO17 (Approx. 8 hours at 0.3L/min)
Formaldehyde	100 μg/m³ 33 μg/m³	NABERS / WHO WELL	Compendium Method TO11A (Approx. 8 hours @ 0.2-0.5L/min)
Acoustic comfort (dB)	35-45 dB	NABERS	Cirrus Class 1 (as per manufacter instructions)
Lighting (Lux)	320 lux– h 160 lux - v	AS1680	Testo 545 (as per manufacter instructions)

In order to evaluate air quality, acoustic, thermal and lighting comfort across the Rose Bowl building a NABERS prescribed minimum number of samples and ISO 17025 accredited measurement methodology was required (NABERS, 2015). Measurements were made in all the major types of spaces that were present across the North, South, West and East sides of the building. As such, measurements were performed in classrooms, offices and lecture rooms. Rooms were selected that represented the whole building in terms of its overall use. In order to sample at many different locations as possible two measurements were undertaken on each of the 5 floors. Ambient conditions on the day were recorded at a roof top location. Table 2 identifies the locations where samples were taken.

Table 2. Sample locations

Location Reference	Level	Wing
Outside – Roof	Roof	Central
Classroom 513	5	NE
Classroom 525	5	NE
Lecture room 538	5	Central
Office 404	4	W
Office 421	4	E
Lecture room 444	4	Central
Classroom 320	3	E
Classroom 307	3	W
Lecture room 241	2	Central
Classroom 208	2	NW
Office 148	1 (Ground floor)	E
Canteen area	1 (Ground floor)	W

Measurements were taken throughout the day and mostly when the locations were occupied. In one instance measurements were taken shortly following a classroom session. All parameters described in Table 1 were measured in all the locations specified in Table 2 with the exception of Formaldehyde and VOCs.

Within 6 weeks of the completion of the IEQ assessment of the Rose Bowl building an online occupant satisfaction survey was designed using an external professional survey team at Berkeley University. At least 40% of the occupancy level for the building responded to the survey; there were 185 respondents out of a building population of approximately 300.

RESULTS

Overall survey and IEQ results

Table 3 summarizes the overall IEQ results for the different parameters indicating which of the locations registered results outside the reccomended range or above the thresholds (NOT MET) identified in Table 1.

The overall results of the occupant satisfaction survey are displayed in figure 1. The scaling identifies level of satisfaction with each issue ranging from 'very dissatisfied' (i.e. 1) to very satisfied (i.e. 7). The results from the Rose Bowl building are compared against average returned results in over 200 other buildings.

Table 3 – Overall IEQ results per locations

Location Reference	Thermal comfort	CO_2	O_3	CH_2O	$PM_{2.5}$	Light	Acoustic
Roof					NOT MET		
Classroom 513						NOT MET	
Classroom 525		NOT MET				NOT MET	NOT MET
Lecture room 538							
Office 404	NOT MET						
Office 421	NOT MET						
Lecture room 444							
Classroom 320	NOT MET						
Classroom 307	NOT MET		NOT MET			NOT MET	
Lecture room 241				NOT MET			NOT MET
Classroom 208	NOT MET						
Office 148				NOT MET			
Canteen area	NOT MET		NOT MET		NOT MET		NOT MET

Figure 1 Overall survey performance (4 = neither satisfied/dissatisfied)

DISCUSSION OF RESULTS

As shown in the overall survey responses (Figure 1) the occupants of the Rose Bowl building are generally neither dissatisfied or satisfied with the building scoring on average 4. Occupants seem to be somewhat satisfied with the general cleanliness and maintenance of the office spaces but slightly dissatisfied with some of the IE parameters such as thermal comfort, air quality and acoustic quality. This general dissatisfaction of some important IE parameters corresponds to some of the IEQ results shown in table 3. The following paragraphs addresses each of the these IEQ parameters and discusses potential improvements.

Thermal comfort

Thermal comfort is a key component of IEQ and has been assessed in this study by measuring air temperature and relative humidity. Other factors such as local climate, thermal radiation and personal factors such as clothing, an individual's level of physical activity and acclimatisation to a climate, can affect an individual's thermal comfort. ASHRAE and NABERS recommends the temperature range of 21–24°C, and humidity of 30-70% and air speeds less than 0.2 metres per second. Figure 2 shows that Temperature was above the recommended range in 60% of the classrooms and in the canteen, whilst relative humidity was within the recommended guidelines in classrooms and offices.

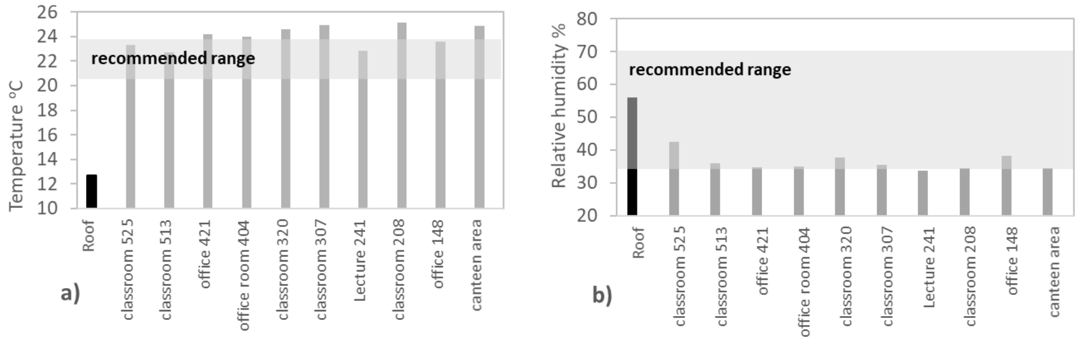

Figure 2 Thermal comfort results: (a) Temperature, (b) Relative Humidity

The occupant survey pointed out dissatisfaction relating to temperature as experienced by staff and students in the Rose Bowl building. Significant numbers reported being dissatisfied with temperature in the building and this potentially affects their ability to work/study. Most complaints were about elevated temperatures in summer and depressed temperature in winter. The classroom measurements of temperature confirmed that they can be high.

Acoustic quality

Acoustic levels in offices were all within the comfort criteria of 35-45 dB, but above the recommended range in one classroom, the main lecture theatre and in the canteen (Figure 3a). While these results may not be an issue for occupants using the canteen poor acoustic performance can be disruptive in classrooms and lecturing spaces. The occupants survey (Figure 3b) revealed that there were a significant number of people who are not satisfied. The core issues of acoustic comfort centres around the ability to have conversations without being overheard or imposing problems on neighbouring staff. A sizeable proportion of those dissatisfied with the acoustic comfort of their space suggest that it may affect their ability to perform their work.

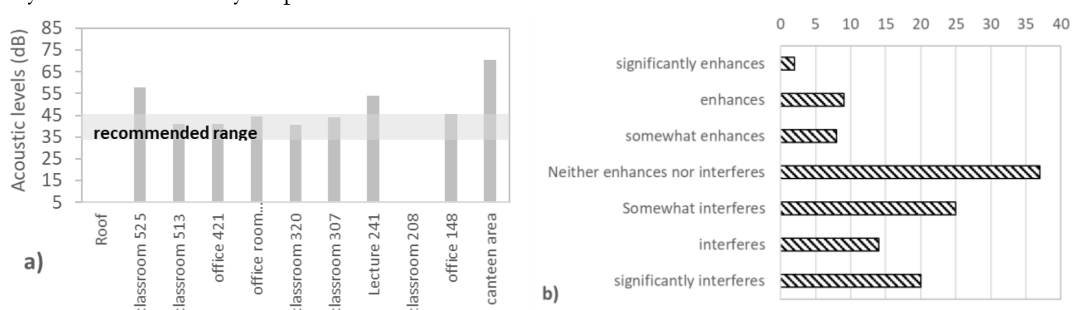

Figure 3 Acoustic quality assessment (a)Acoustic levels and (b) No. of responses to the following question "Overall, does the acoustic quality in your workspace enhance or interfere with your ability to get your job done?"

Indoor Air Quality

Ventilation effectiveness versus carbon dioxide (CO_2) levels:

In order to assess IAQ and therefore test the performance of the ventilation system in a building, measuring concentration of CO_2 is useful. Ventilation rates do not directly affect occupant health, but they may affect perception outcomes, as well as indoor environmental conditions. CO_2 measurements can be used to determine if the HVAC system is balanced and provides adequate ventilation to the building occupants. ASHRAE and NABERS recommend a maximum 1000ppm for CO_2 for indoor environments (ASHRAE 62) while the WELL building standard recommends a maximum of 800 ppm. Figure 4 shows the results for the CO_2 concentration as measured, as well attitude to air quality when asked to comment on its stale or stuffiness.

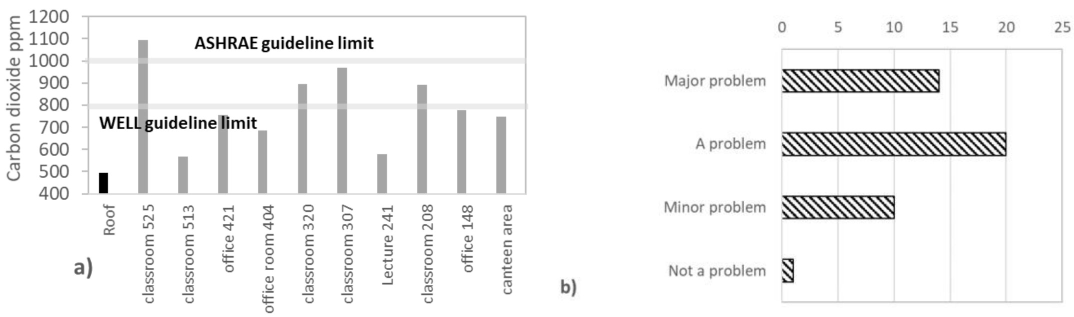

Figure 4 Ventilation results (a) CO_2 results (b) No. of responses to the following question "You have said that you are dissatisfied with the air quality in your workspace. Please rate the level of each of the following problems. - Air is stuffy/ stale"

The survey responses indicated that occupants are dissatisfied with the air quality in their workplace for which they specifically indicated the problem to be the air being stale or stuffy, with 98% of the responses considering this to be a problem (Figure 4b). This issue is usually related to ventilation issues due to an increase in CO2 levels. Looking at Figure 4a it is possible to see that one location exceeded the ASHRAE threshold of 1000 ppm and that four locations exceeded the WELL building standard limit of 800 ppm. This may suggest that the results may not be representative of the overall IE conditions throughout the whole year across all the locations in the building, but they do indicate that the ventilation strategy is not effective on all places. Considering the limit of 800 ppm then we can easily see that four out of five classrooms (80%) were above the recommended range which suggests that ventilation may not be effective during work hours.

Pollution control: Exposure to excessive levels of air pollutants can cause short term symptons such as nausea, headaches, allergic reactions and respiratory irritation. Long-term symptons from exposure to air pollutats may include central nervous system damage, endocrine disruption and cancer. Therefore, it is critical for a building to meet a basic level of IAQ. The results shown in Figure 5 evidence the presence of three different air pollutants: fine particulate matter ($PM_{2.5}$), Ozone (O_3), and Formaldehyde (CH_2O). All of which are above the recommended thresholds.

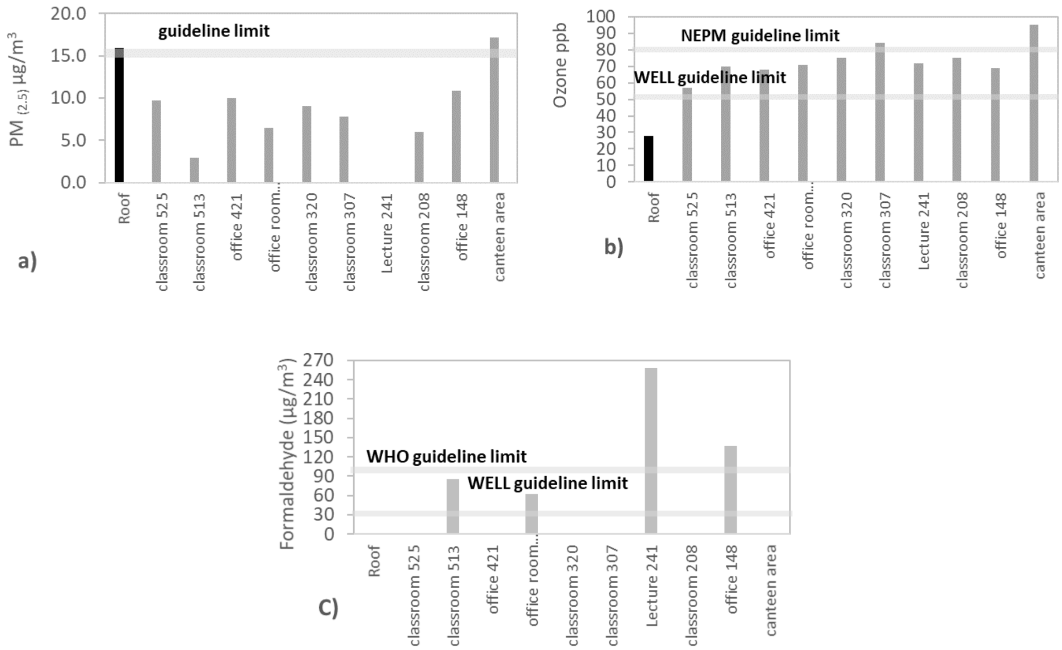

Figure 5 Air pollutants results: (a) $PM_{2.5}$, (b) Ozone and (c) Formaldehyde

Figure 5a shows the levels of $PM_{2.5}$ to be acceptable in all locations except the canteen. The Canteen area is located near the entryway lobby of the building at ground level which faces on to a busy road. The busy road may be the primary entry point for particulates into the canteen. Improving ventilation through air curtains may be the best way to limit ingress of the particles. It is also worth noting that since occupants only spend a short period of time at the Canteen overall health exposure will be low for most people using the building.

The levels of O_3 (Figure 5b) were above the recommended guideline for the WELL building standard, however is not a pollutant of concern in NABERS IE. This demonstrates the importance of determining the purpose of any building assessment and thus which standard ought to used.

Formaldehyde concentratons are shown in Figure 5c, it is evident that in all the locations the levels exceded the WELL building standard guideline, and 50% of the locations exceeded the WHO threshold of 100 μg/m^3 (30-minute exposure). Formaldehyde is used for manufacturing melamine and phenolic resins, fertilizers, dyes and embalming fluids. Short-term exposure to formaldehyde can cause eye, nose, or throat irritation, coughing or wheezing, and nausea while long-term exposure can cause severe skin irritation, respiratory problems and an increased risk of cancer. These results indicated that the filtration and ventilation system was not effective enough at controlling emissions from within the building. Given the seriousness of discovering elevated Formaldehyde the Esates Team sought to focus on addressing the issue as opposed to further pursuing the NABERS IE certification.

The Estates team at the University responded quickly to the initial findings by increasing ventilation rates to the affected areas. Variable speed drive controls were reconfigured to provide 10% more ventilation during quieter periods of the day. A second air quality assessment for formaldehyde was performed in the Rose Bowl two months after the initial assessment. The re-test included two additional Lecturer rooms (Lecture room 538 and Lecture room 444). Figure 6 reveals the results for formaldehye (Figure 6a) as well as CO_2 (figure 6b). The levels of Formaldehyde dropped below the threshold guidelines as well as the CO_2 concentration. This indicates that the revised ventilation strategy was responsible for keeping levels of formaldehyde below the recommended exposure guidelines.

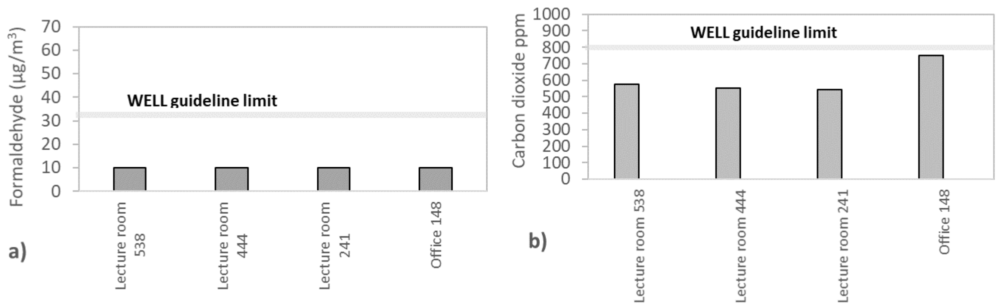

Figure 6 Second air quality assessment results: (a) Formaldehye (b) CO_2

CONCLUSION

This paper has shown that new buildings rated as "excellent" under sustainability assessments such BREEAM could potentially fail under different ratings tools that are focused on the health and wellbeing of occupants. NABERS is a useful tool for measuring health and wellbeing of occupants and the combination of measurements and surveys is the best way to perform such assessments. Based on the NABERS methodology it was possible to identify issues that were impacting occupant's wellbeing, such as elevated temperature, poor IAQ (elevated CO_2 and formaldehyde) and noise intrusion. By assessing actual building performance under schemes such as NABERS IE facilities managers can better understand how their buildings affect people within them. This might mean having to compromise on energy efficiency strategies that do not consider health and wellbeing impacts. The approach taken by the building managers for the Rose Bowl has involved having to provide more menchanical ventilation in rooms when not in use, in order to ensure they are healthy and comfortable places to work and study.

This paper has also shown the importance of understanding how different rating tools affect an overall assessment of buildings even under the same health and wellbeing focus. There is evidence to show that greater effort may be needed to widen the pollutants that are examined when using any health and comfort assessment tool.

ACKNOWLEDGMENTS

Estates Services team at Leeds Beckett University.

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